

A Medium Access Control for the Infraless Peer Aware Communication Networks

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Abstract— In this paper, the peer aware communication (PAC) network is introduced as an infraless area network which supports peer group communication for the low power wireless devices. For providing efficient synchronized group communication, the PAC MAC superframe is suggested. To avoid interference among neighboring peer groups implicitly and to support the variety of required quality of peer group services, the cyclic-superframe structure is proposed. The PAC devices can communicate with less power consumption by configuring a cyclic-superframe structure aligned with the service traffic, and can avoid interference to neighbor peer groups by selecting the start time of peer group communication.

Keywords – peer aware communication; IEEE 802.15.8; superframe; cyclic-superframe

I. INTRODUCTION

There is a demand for wireless communication capable of providing multiple service qualities by forming a peer group with low power devices, which can be operated in crowded places such as a shopping mall, an amusement park, a stadium, or which can work as an emergency communication infrastructure in case of network lost due to a natural disaster. The legacy infrastructure-based communication network may have difficulties to configure and manage the network for dynamically providing social network services, games, and advertisement services simultaneously among hundreds of thousands devices within a close range with the efficiency of use of radio resources.

IEEE 802.15 Working Group initiates a project, Peer Aware Communication (PAC), to develop a standard that low-power device can form a peer communication group without a coordinator. Peer-to-peer communication is a communication method that supports direct device-to-device communication to provide peer-to-peer services. The peer can be recognized by a communication interface or recognized by proximity such as neighboring events, people, location-based information, or recognized by interests of peers such as shopping and games.

The IEEE 802.15 Task Group 8 develops PAC network standard [1];

- is fully distributed wireless network with no network infrastructure
- searches a peer in range without link access procedure
- supports at least ten peer-to-peer groups at the same time

The IEEE 802.15 TG8 completed the first Working Group Letter Ballot in June 2016 and aims to publish the standard in September 2017.

The PAC MAC link resource is controlled to share a dedicated time period, which is designed for synchronization, discovery, peering, contention access, or contention free access, between adjacent PDs even though they belong to different PAC groups. For this, PAC MAC superframe and network synchronization function are defined.

In this paper, the peer aware communication (PAC) network is introduced as an infraless area network to provide peer group communication for the low power wireless devices. For efficient synchronized group communication, the PAC MAC superframe is defined. To avoid interference among neighboring peer groups implicitly and to support the variety of required quality of peer group services, the cyclic-superframe structure is proposed.

II. INFRALESS PEER AWARE COMMUNICATION NETWORKS

Peer Aware Communication Network consists of PAC Device (PD). PD can set one-to-one unicast, one-to many multicast, n-m multicast, and broadcast link between peers as shown in Figure 1.

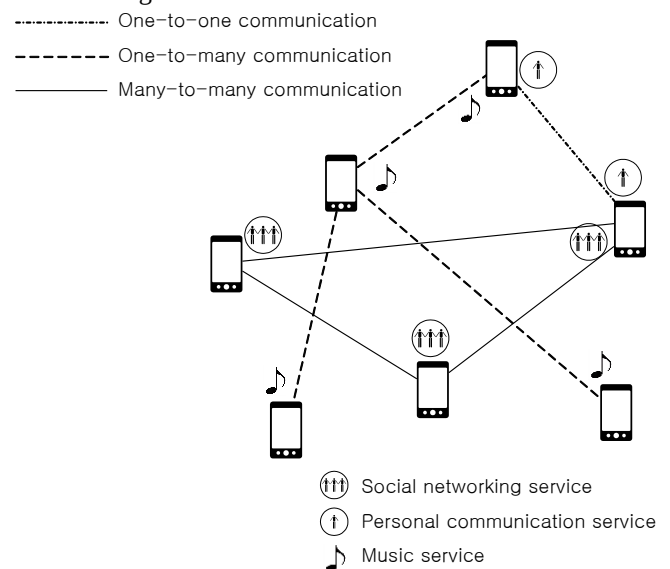


Figure 1. PAC communication links [1]

A PAC device of IEEE 802.15.8 consists of at least one PHY and MAC. Typical functions are shown in Figure 2. The PD PHY layer provides OFDM, OFDMA and UWB transceivers and provides network synchronization, channel state information feedback, power control, random access and security protocol. The PD MAC layer performs PD searching, peering, and unicast/multicast data transmission. The upper layer of the PD provides peer device information management, peer device group configuration and management, and peer service.

IEEE 802.15.8 PAC provides a PAC network which is capable of supporting up to ten peer-to-peer services simultaneously for a PD.

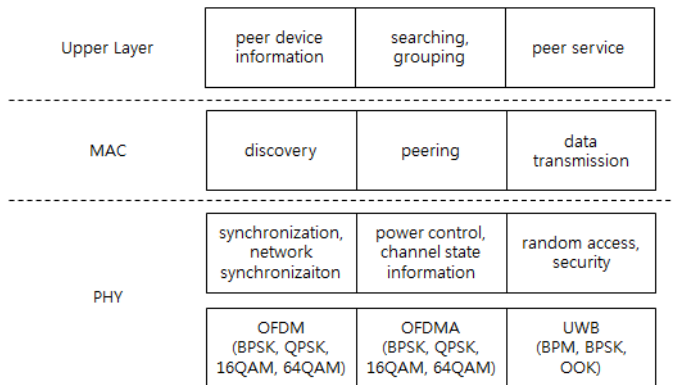


Figure 2. PAC network layers

Peer Aware Communication PHY layer is provided with low-rate mobile PHY, high-rate mobile PHY, and UWB PHY. The applied frequency band and modulation are shown in Table 1.

Table 1. PAC frequency band and modulations [1]

Frequency band (MHz)	Modulation		Multiple antennas
2400 – 2483.5 5725 – 5875	OFDM	BPSK, QPSK, 16QAM, 64QAM	Beamforming
915.9 – 929.7	Filtered OFDM	GFSK	
2400 – 2483.5 5725 – 5875	OFDMA	BPSK, QPSK, 16QAM, 64QAM	MIMO
3100 – 10600	UWB	BPM-BSPK, OOK	--

The low-rate mobile PHY provides 3, 6, 9, 12, 17.5, 24, 36, 45, and 54 Mbps transmission rates depending on the modulation method in OFDM operating in 2.4 GHz and 5.7 GHz bands.

The high-rate mobile PHY provides transmission speeds of at least 1 Mbps to 372.96 Mbps depending on the modulation method in OFDMA operating in Sub-GHz, 2.4 GHz, and 5.7 GHz bands.

The UWB PHY operates at 4.2 ~ 4.8GHz and 6 ~ 10.6GHz band, and provides transmission speeds of 0.85, 6.81, and

27.24 Mbps at a minimum of 0.11 Mbps depending on the modulation method.

As shown in Figure 3, the low-rate mobile PHY and the high-rate mobile PHY transmit a frame at the designated period in a superframe, which is time-divided by a synchronization period (SP), a discovery period (DP), a peering period (PP), a contention access period (CAP) and a contention free period (CFP).

The low-rate mobile PHY transmits a PHY frame composed of a short training field, a long training field, a contention window, a PHY header, a PSDU, and a bit jitter.

The high-rate mobile PHY transmits a PHY frame composed of a preamble, a PHY header, and a PSDU.

In the PAC network, the superframe is operated in synchronization with not only the PDs in the PAC group but also the different PAC groups.

For PAC network synchronization, a synchronization period of 306 us is dedicated for transmitting a synchronization signal. The synchronization period consists of 34 back off slots with two symbol lengths. Synchronization signal is 6 symbols and consists of a short training field, a long training field, a timing offset field, and a contention window. Three slots are required to transmit one synchronous signal. The exponential increase exponential decrease (EIED) backoff algorithm determines the number of PDs capable of simultaneously transmitting synchronous signals in one synchronization period.

- If the PD is initialized, the MAC layer shall perform initial synchronization. It must be turned on for five superframes to detect the sync signal. If it does not receive the synchronization signal from the peer PDs, it must transmit the synchronization signal. After synchronization, the synchronization period should remain active at all times.
- The PAC network must maintain network synchronization, and if the network synchronization signal is not received during five consecutive superframes, the synchronization is considered to be lost.

III. IMPLICIT MEDIUM ACCESS CONTROL

Peer Aware Communication MAC layer provides superframe/cyclic-superframe medium access control, peer device discovery, peering, and data transmission.

The PAC MAC link resource is shared with adjacent multiple PAC groups. For efficient synchronized group communication, the PAC MAC superframe is defined. The PAC MAC superframe consists of a synchronization period of 306 us, a discovery period of 1ms, a peering period of 10ms, a contention access period of 40.694ms, and a contention free period of 48ms, as shown in Fig. 3.

In the synchronization period, synchronization signals of 6 symbol lengths are transmitted.

In the discovery period, the 21-byte PD service identifier provided by the PD service is transmitted. High mobility PHYs use the discovery resource block.

In the peering period, peering and de-peering MAC command frames are exchanged by contention access.

The discovery request and response command frames are exchanged in the contention access period.

The contention free period is divided into resource scheduling request period, scheduling response period, pilots from Tx, and channel quality indicator (CQI) from Rx. In resource scheduling request period and scheduling response period, resource elements are reserved according to priority and transmission size by using scheduling request message and scheduling response message.

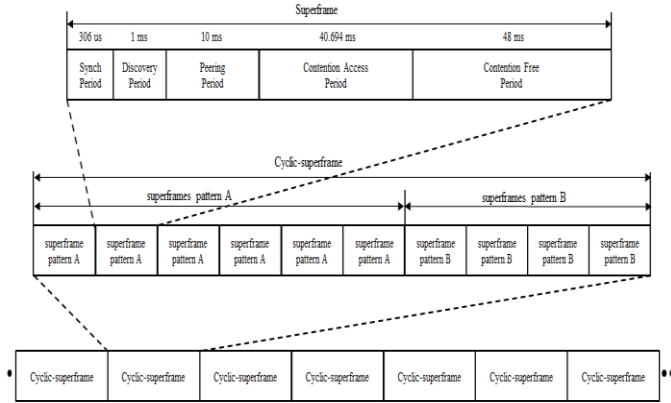


Figure 3. PAC MAC superframe and cyclic-superframe

In PAC MAC, as the contention access method, the exponential increase exponential decrease backoff algorithm and the p-EIED backoff algorithm are applied. [1]

The EIED backoff algorithm is designed to obtain a small variation of contention window (CW) between PDs by maintaining a constant transmission rate regardless of PD density when updating the CW. After calculating the average inter-arrival time including the weight at the inter-arrival time between the recently received two synchronous signals, the average inter-arrival time is compared with the reference time to maximize the probability of receiving the synchronous signal within the synchronization period. If it is small, the size of CW exponentially increases, and if it is large, CW exponentially decreases. The CW update rate is determined according to the CW average of the peripheral PD and the CW of the received synchronization signal in CW update.

The p-EIED backoff algorithm adjusts the data frame rate by attempting to transmit a data frame with a probability of p for each backoff slot to minimize the persistence level p , which is the average transmission rate difference between PDs.

The contention method of each period is as follows.

- The synchronization signal is transmitted through a slotted CSMA/CA (carrier sense multiple access with collision avoidance) using the EIED backoff algorithm.
- The peering period uses p-EIED random access and CS mechanism.
- CAP occupies the link with p-EIED random access method and uses CS mechanism using RTS and CTS when transmitting data frame.

Since the PAC MAC superframe uses a period of fixed length for each use, it is difficult to satisfy the following requirements.

- It should be possible to reserve some number of superframe periods for guaranteeing the quality of transmission for an application service.
- It should be able to configure the number of superframe and on/off of each superframe period adequate for communication phase, discovery phase, peering phase, and data transmission phase of an application service.
- It is able to select combination of superframe periods on/off that can minimize interference between adjacent PDs or PAC groups.

To support the above requirements, it needs to specify the on/off state of each period of multiple superframes. As a solution, a cyclic-superframe structure is proposed; multiple PAC MAC superframes can be grouped in a cyclic-superframe for specifying each period of a superframe as enable or disable.

The cyclic-superframe structure consists of multiple superframes which has two active period patterns, pattern A and pattern B, as shown in Figure 3. The active period pattern can be identified by four bits indicator: the first bit for discovery period, the second bit for peering period, the third bit for CAP, and the fourth bit for CFP, which set to one for active period. The cyclic-superframe consists of n pattern A superframes starting from the beginning of the cyclic-superframe, and then filling the rest with the pattern B superframes.

Figure 4 a) shows a cyclic-superframe with five pattern A superframes, each with SP and DP active ($b_4'1000$), followed by one pattern B superframe with SP, DP and CAP active ($b_4'1010$). This example cyclic-superframe could be used for supporting energy efficient data transmission by transmitting a data frame over the CAP every six superframes. Figure 4 b) shows a cyclic-superframe with three pattern A superframes each with SP, DP, PP and CFP active ($b_4'1101$), followed by six pattern B superframes with SP active ($b_4'0000$). This example cyclic-superframe could be used for supporting burst reliable data transmission by using three consecutive data frames transmissions over the CFP, before sleeping for the duration of six superframes.

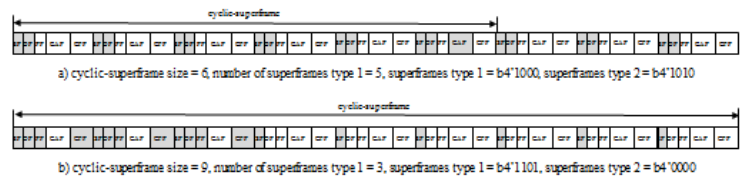


Figure 4. Examples of cyclic-superframes structure [1]

In order to avoid the interference among the neighbor PD or PAC groups implicitly, the cyclic-superframe structure information is informed to neighbors by adding a 4-byte cyclic-superframe descriptor to the header of transmitted frames. The cyclic-superframe descriptor consists of the length of the cyclic-superframe represented by the number of superframes, the number of pattern A superframe, indicator of superframe pattern A, and indicator of superframe pattern B. The newly formed neighbor peer group may select the start

time of peer group communication with collected information of neighbor peer groups' cyclic-superframe structure.

IV. CYCLIC-SUPERFRAME OPERATION FOR PAC

To show how cyclic-superframe structure is operated on peer services, we consider that three different peer service groups are operating within communication range as shown in Figure 5.

The service of peer group A is on-line game;

- initiator invites on-line gamers and waits for 10 minutes
- initiator forms a peer group and starts a game
- game control messages are exchanged among gamers every 500 ms

The service of peer group B is advertisement;

- advertiser sends advertisement to customers in the shopping mall every 1 sec
- customer starts to search advertisement for 30 minutes while locating in the mall

The service of peer group C is equipment control;

- equipment controller discovers sensing and actuation devices all the times
- sensing device sends data every 10 sec
- equipment controller sends control data every 10 sec
- sensing device should send urgent signal no later than 100 ms

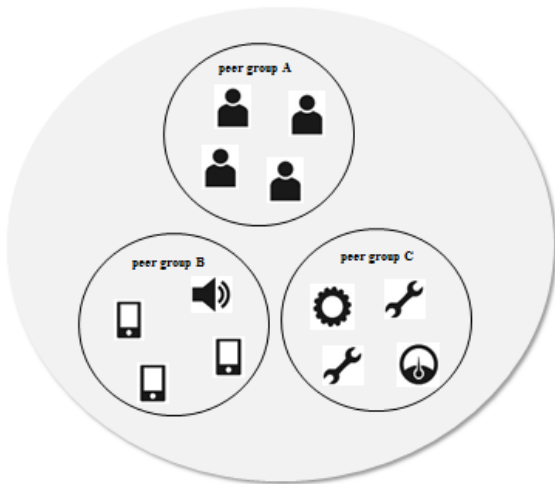


Figure 5. Example of peer group services

Each peer group has different discovery procedure and data transmission pattern, as shown in Figure 6. The peer group A starts data transmission phase after discovering game partners and peering with all participants. Any participating device can leave from the game PAC group, but no new device is expected to join the PAC group after commencing the game. For the peer group B, advertiser continues to discover a peer. Any peer device can join a peer group by responding to an advertiser. After transmitting advertisement data, peering between the advertiser and the customer is released. For the peer group C, equipment controller continues to discover a peer device. After peering, the device will remain in data transmission phase.

Those requirements on discovery, peering and data transmission phase of each service are considered in usage of the cyclic-superframe; selecting the start and stop time of discovery phase, the frequency of discovery request, the duration of peering phase, and the duration of data transmission phase. Each peer group can select the cyclic-superframe structure adequate for the traffic characteristics of the application at each communication phase; active period pattern A and B, the size of the cyclic-superframe, and ratio of pattern A superframes and pattern B superframes.

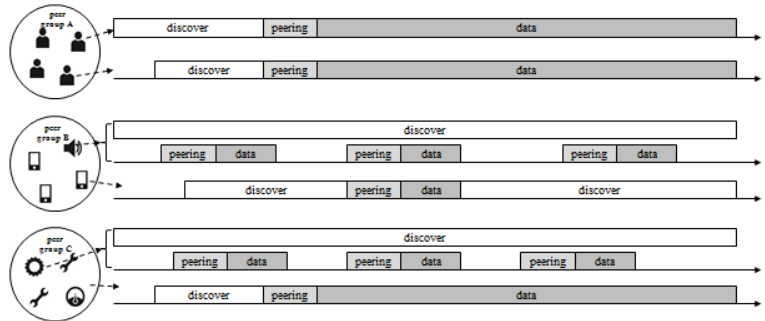


Figure 6. Cyclic-superframes for variety of services [2]

If a peer device joins multiple peer groups, the device manages the access to the MAC link according to the active periods combined multiple cyclic-superframe of peer groups, as shown in Figure 7. The peer device can identify in which period of the superframe contention will be high. The peer device can increase the transmission success rate of a high priority device by regulating the low priority devices access.

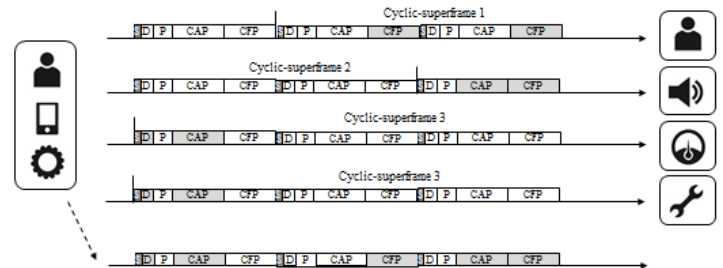


Figure 7. Access control of combined multiple cyclic-superframes [2]

The newly formed peer group listens discovery request messages or peering messages broadcasting from the neighbor peer groups and collects information of cyclic-superframe structure. In order to avoid the interference among the neighbor PAC groups implicitly, the peer group calculates the contention probability of each period of a superframe by projecting new cyclic-superframe structure over combined multiple cyclic-superframe of peer groups. The peer group selects the start time of peer group communication to let newly joined cyclic-superframe induce the lowest contention.

V. CONCLUSIONS

IEEE 802.15 Working Group develops Peer Aware Communication (PAC) standard that low-power device can form a peer communication group without a coordinator. The PAC MAC link resource is shared with adjacent multiple PAC peer groups. For efficient synchronized group communication, the PAC MAC superframe is defined. To avoid interference among neighboring peer groups implicitly and to support the variety of required quality of peer group services, a cyclic-superframe structure is proposed.

The PAC devices can consume less power by configuring the cyclic-superframe structure aligned with the service traffic, and can avoid interference to neighboring peer groups by selecting the start time of peer group communication.

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Seong-Soon Joo received the B.S. from Hanyang University in 1980, and received the M.S. and the Ph.D. degree from Seoul National University, Korea, in 1982 and 1989 respectively, all in electrical engineering. He joined ETRI (Electronics and Telecommunications Research Institute) in 1983, where he is currently a principal member of the research staff with the Department of Knowledge converged Super

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